imagination at work

Sorbent Injection Sox Control
Combustion Optimization
Generation Optimization

U.S.-China NOx and SO2 Control Workshops

Shenyang, Liaoning Province, P.R. China

3-7 November 2003

GE Environmental Energy & Optimization Services

Coal-Fired Boiler Issues/Problems

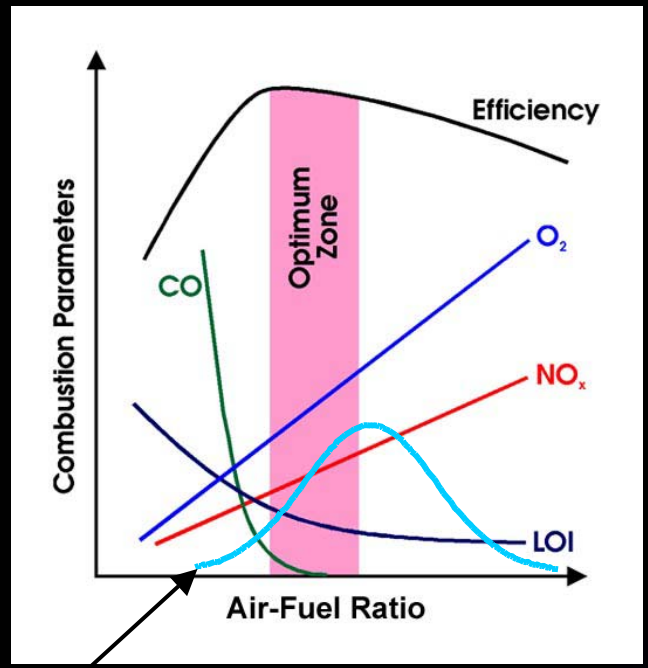
- Reduced steam generation
- Off design steam temperatures
- Reduced boiler efficiency
- Slagging and fouling/deposits
- High emissions (SO_2, NO_X, CO) and carbon loss
- Tube overheating and leakage
- Poor combustion

Combustion Plays a Significant Role in Many Issues

Coal Combustion

Many Issues Relate Back to Fuel-Air Control

- Limited capability to control coal & air flow distribution to each burner
- Historical boiler capability
  - Coal flow bias up to +/- 30%
  - Combustion air flow bias up to +/- 20%
- Large burner-to-burner fuel-air ratio imbalance of up to +/- 36%



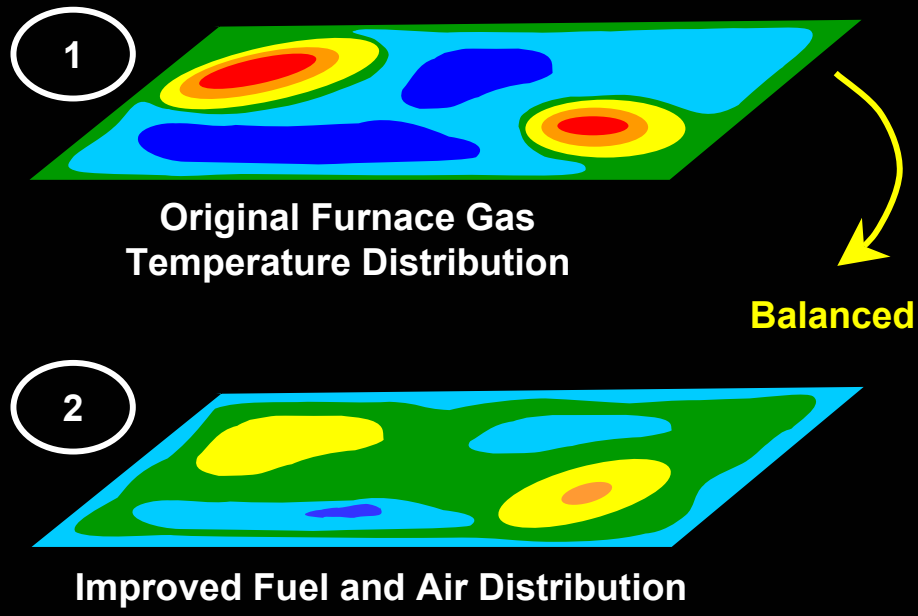
Burner Air-Fuel Distribution

Poor Individual Burner Control Can Result in Higher Overall Excess Air and Performance Loss

Coal Combustion

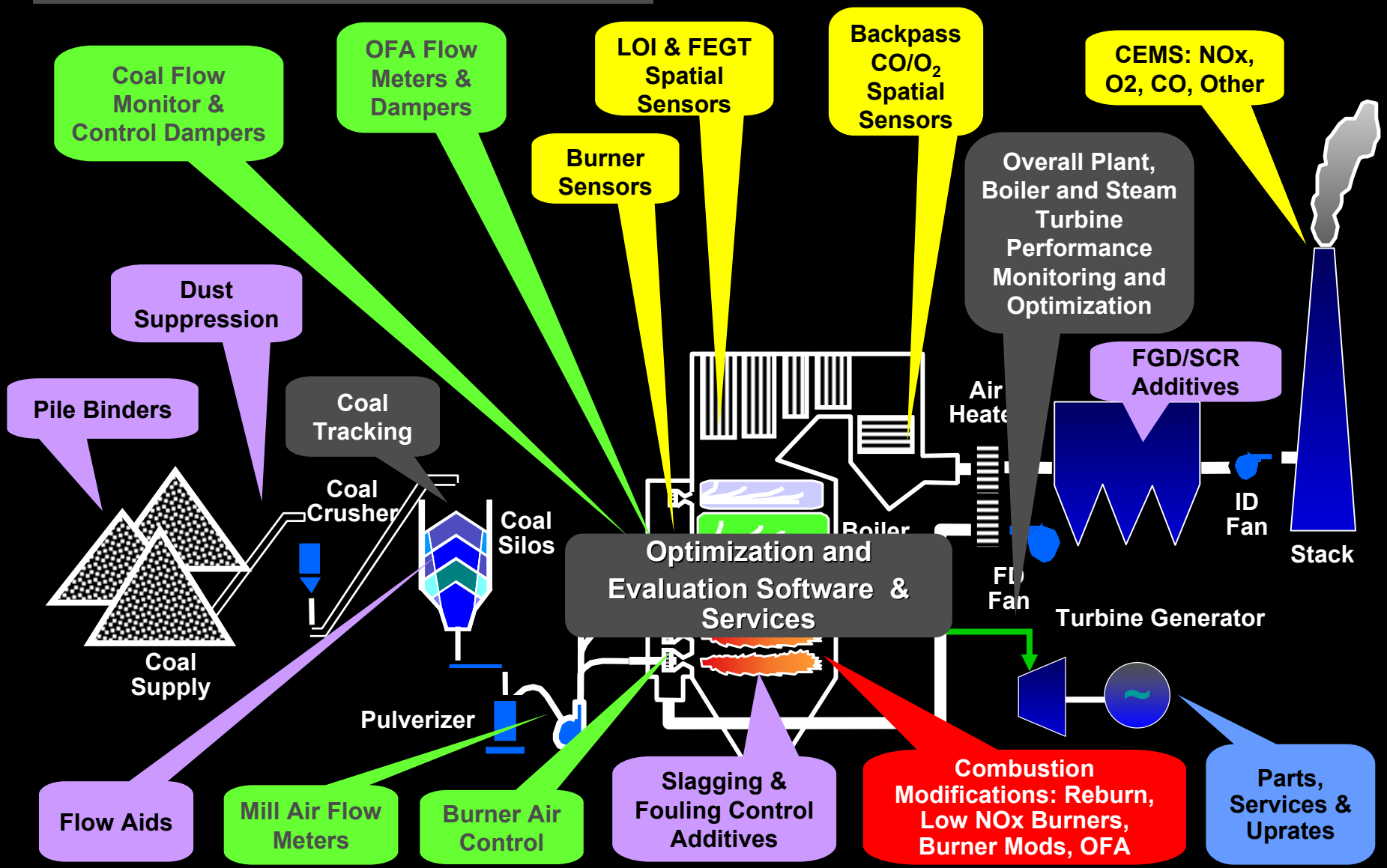
Fuel-Air Control Can Impact FEGT (Furnace Exit Gas Temp)

- Burner-to-burner air-fuel imbalances can produce local hot wall or gas temperatures
- Non-uniform temperatures can lead to local slagging and fouling
- Increased slagging and fouling can result in boiler derate or outage

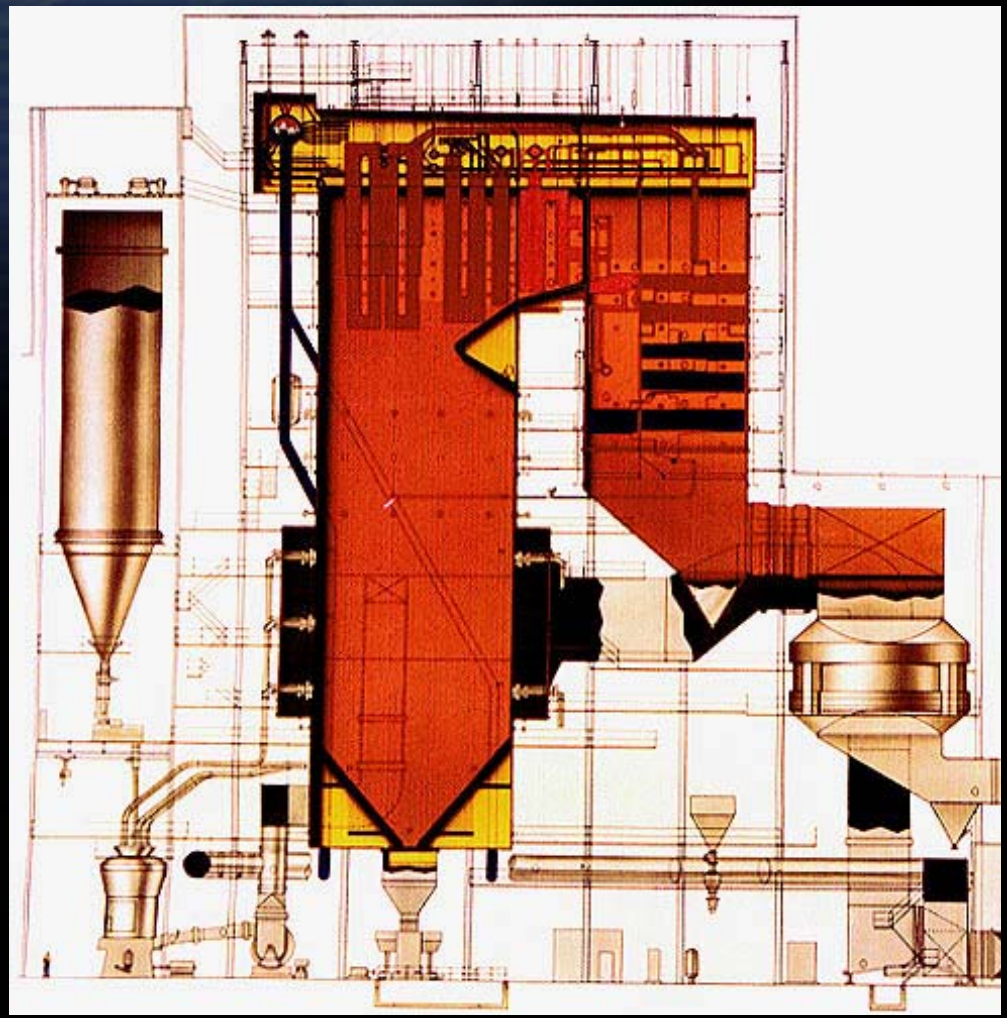


Improved Zonal Control Can Improve FEGT Uniformity and Help to Minimize Slagging

Plant Optimization



Combustion Optimization



Unit Characteristics

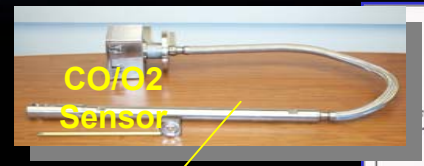
- Nominal Full Load: 380 MWg
- Design: Opposed-Wall Fired
- Coal: Powder River Basin

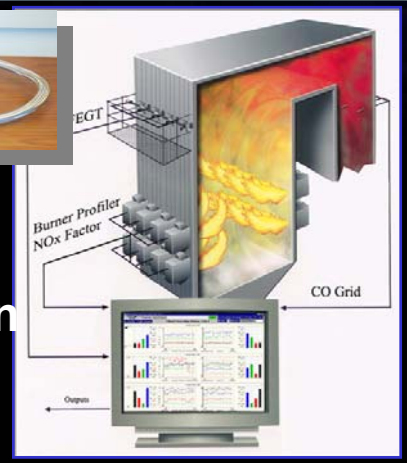
GE Optimization Solution

- Combustion Sensors
- Automated Coal Flow Balancing System
- Overfire Air (Spring 2004)
- Advanced Controls System (Spring 2004)

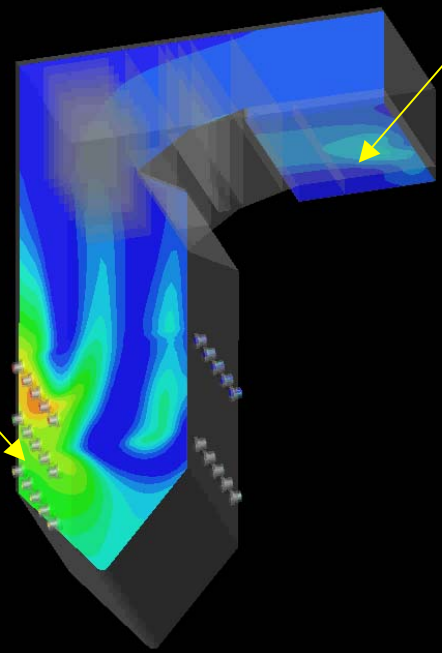
Coal Plant Combustion Optimization

Custom Engineered Furnace Modifications

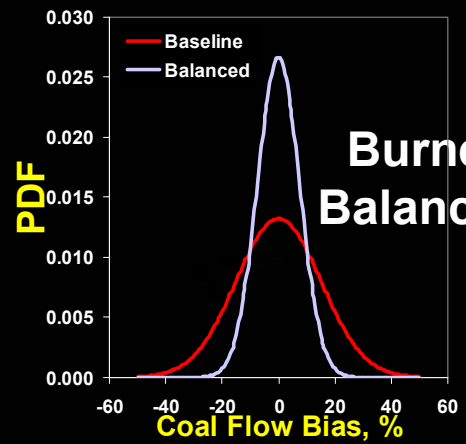




Furnace Combustion Sensor Arrays

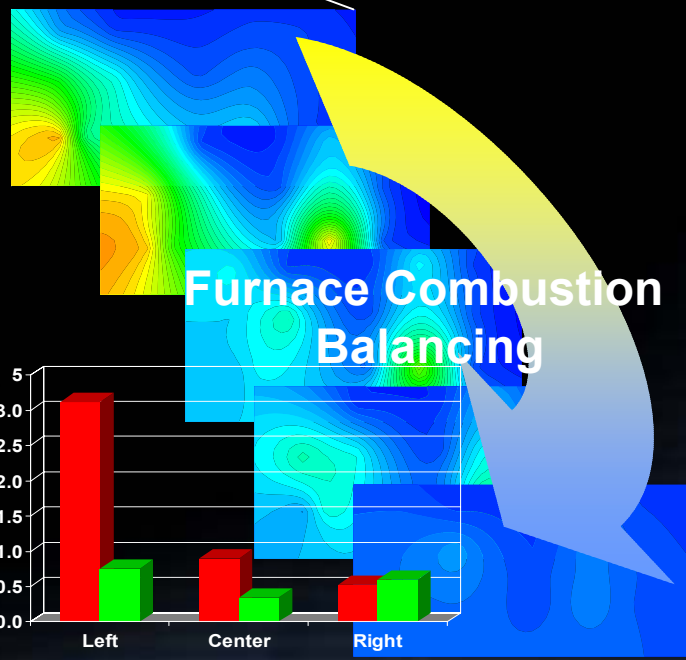


Burner Fuel/Air Flow Sensors & Auto-Control



Burner Balancing

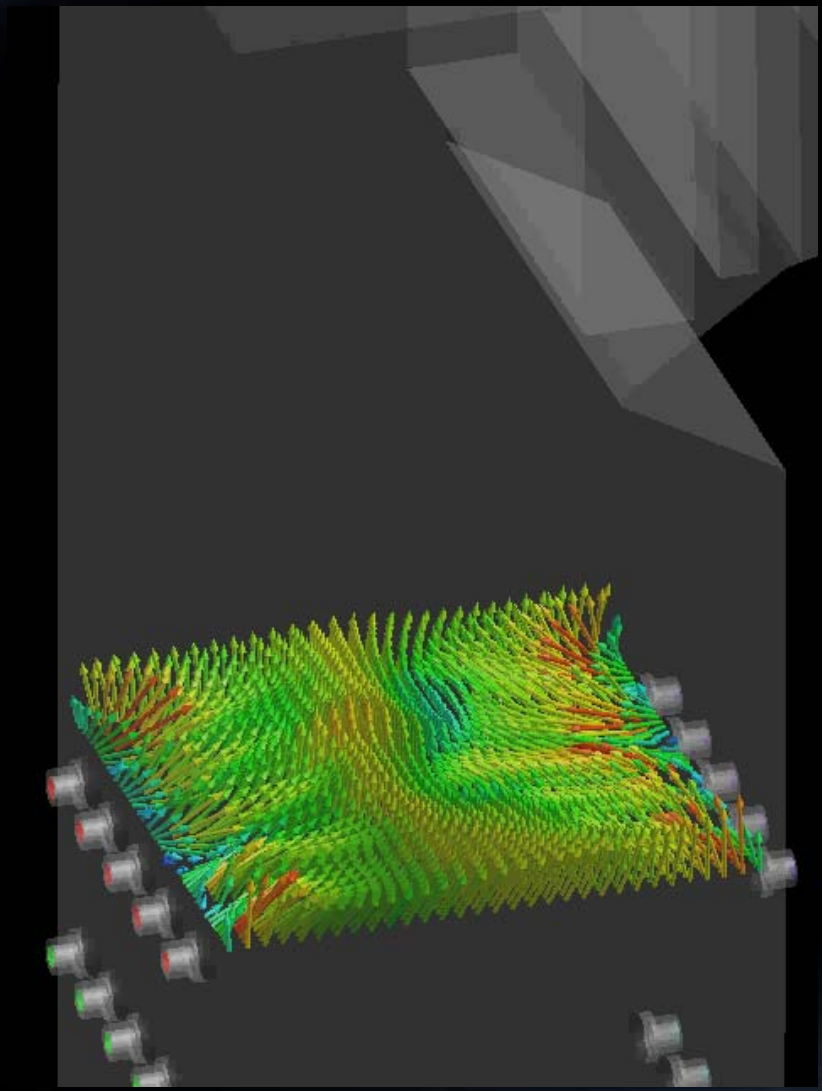
Burner Tracking



Combustion Optimization

Baseline Unit Characteristics

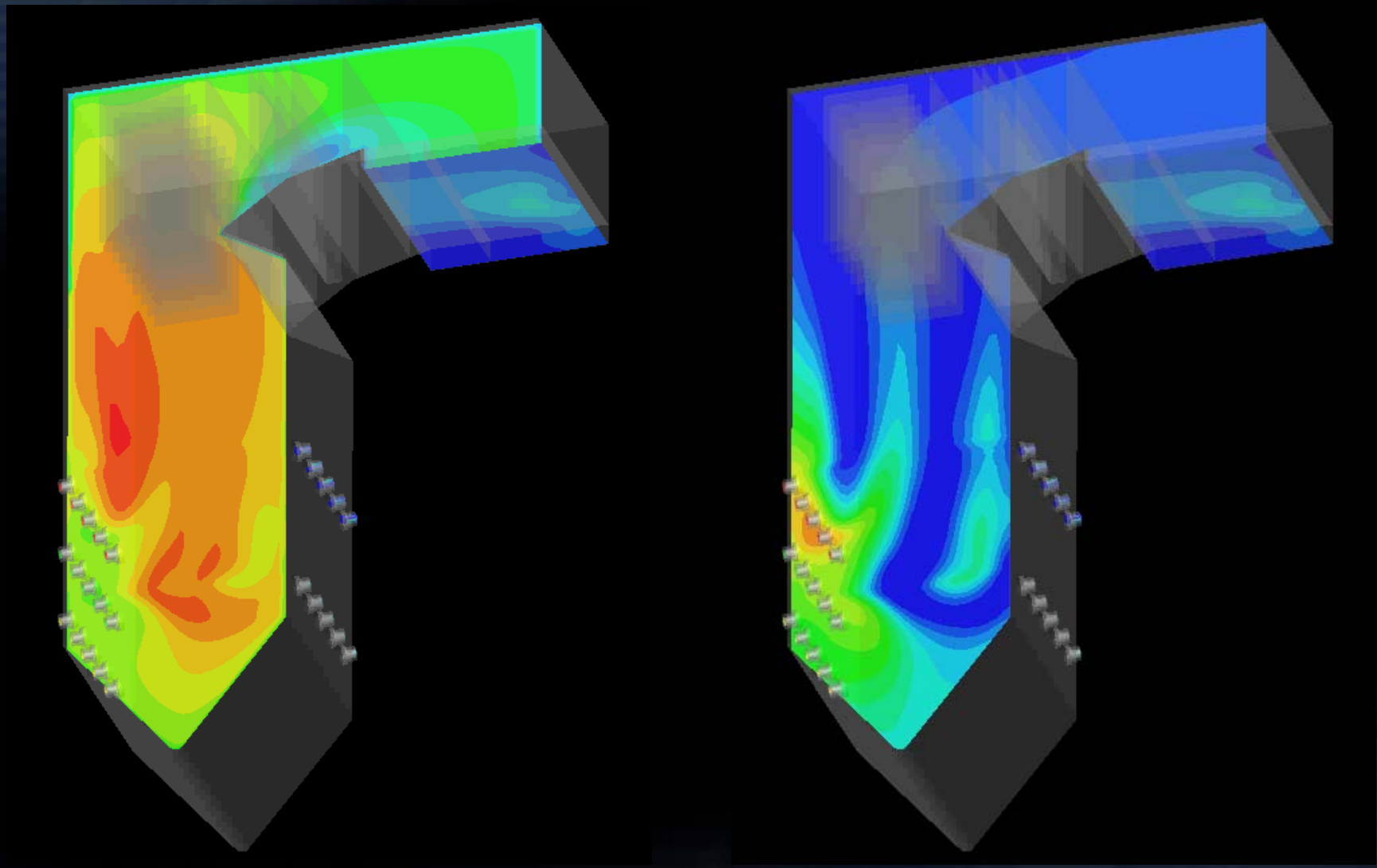
Velocity Field



Combustion Optimization

Baseline Unit Characteristics

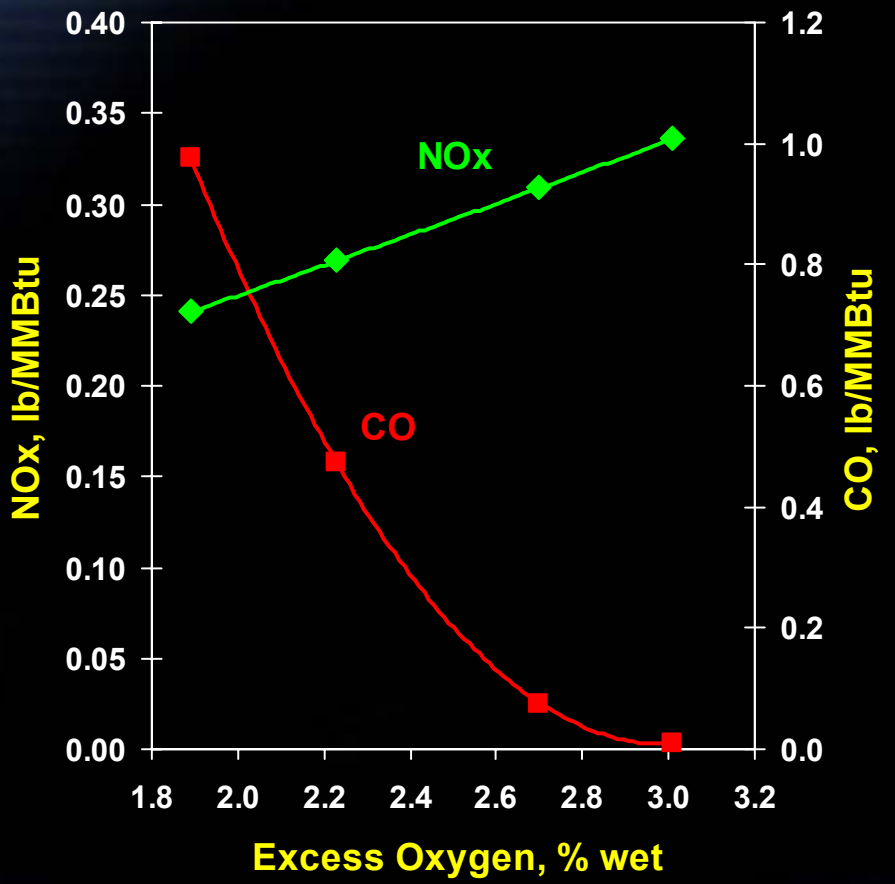
Temperature & Oxygen Profiles



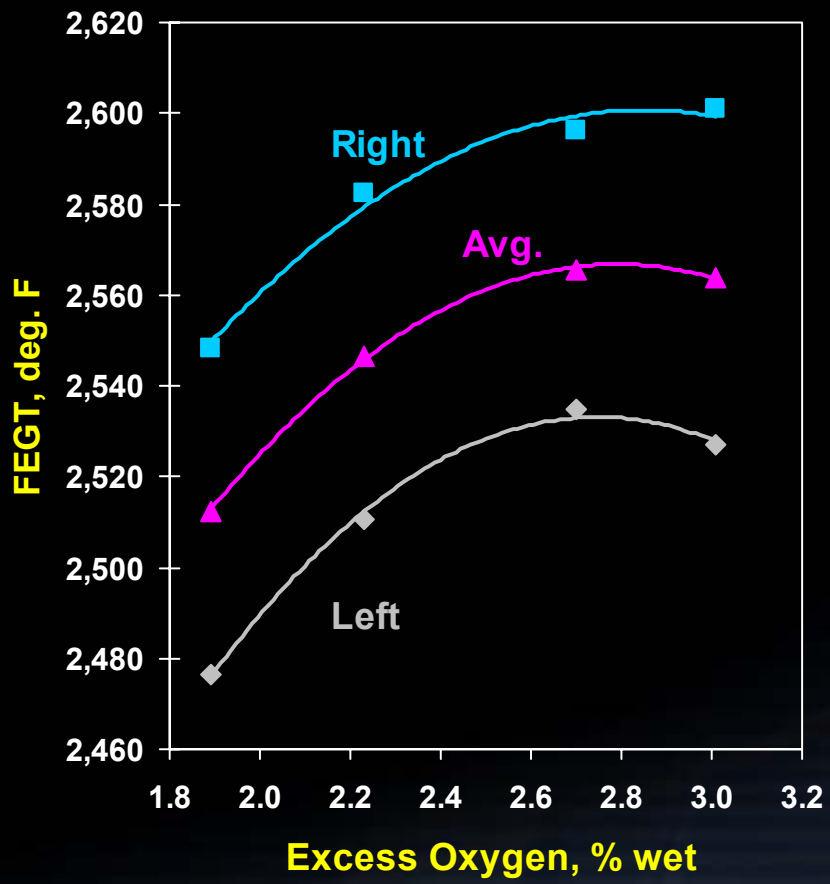
Combustion Optimization

Baseline Unit Characteristics

NO_X & CO Emissions

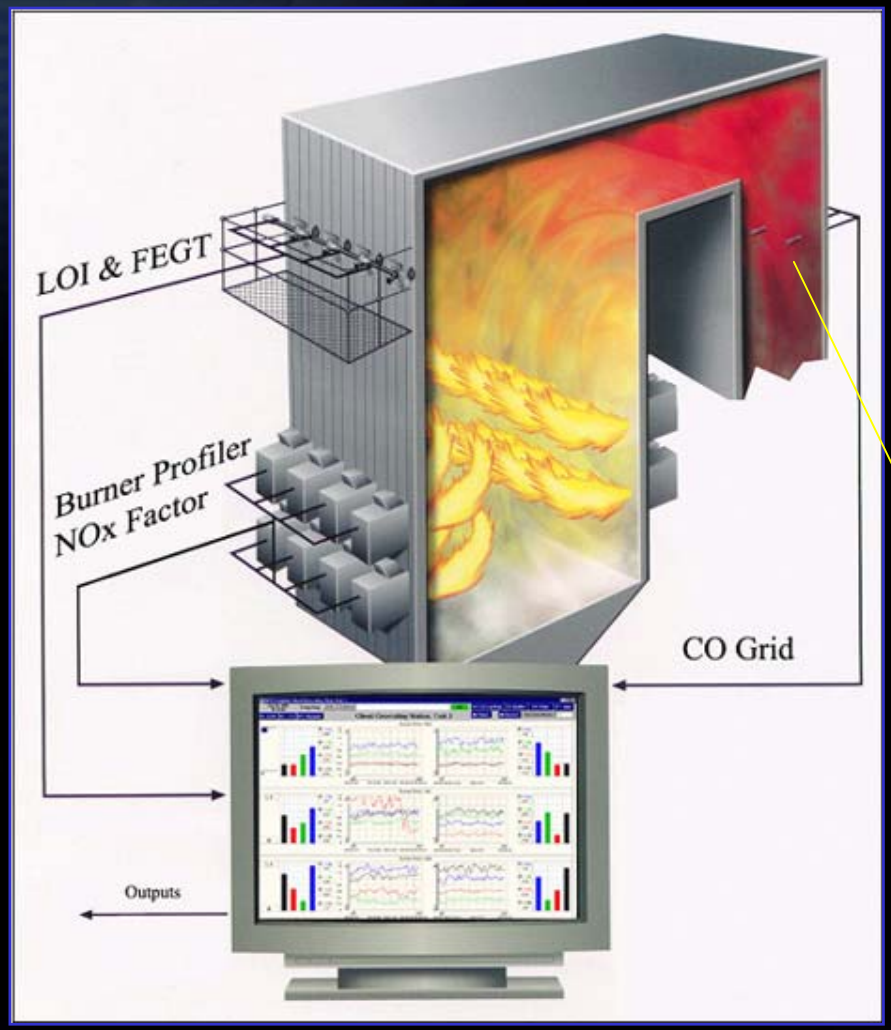


FEGT



Combustion Optimization

Combustion Sensors



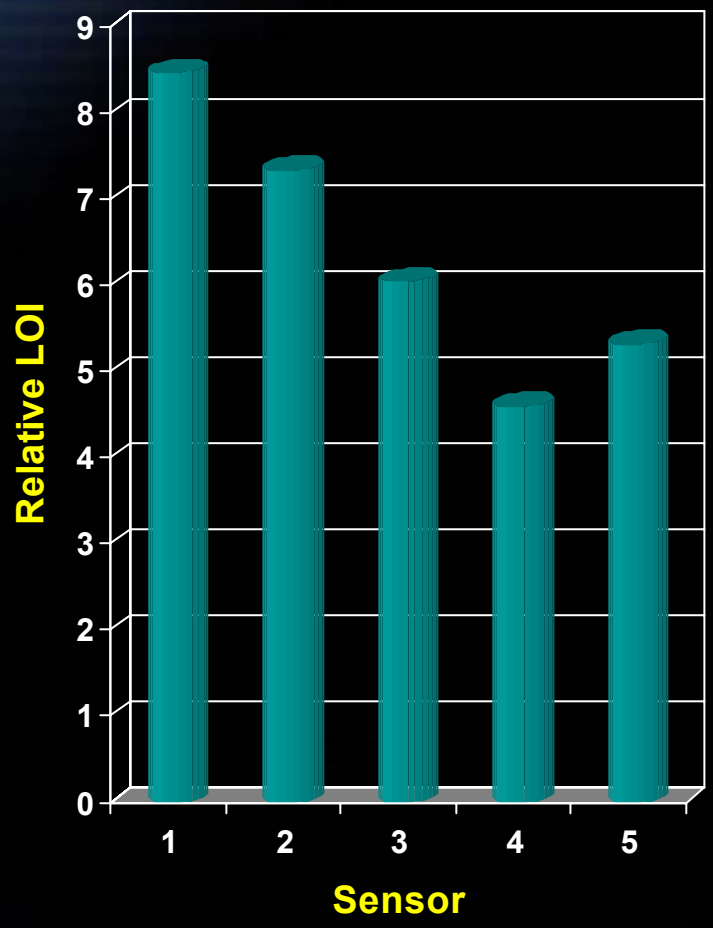
- **Sensors Installed:**
  - CO Grid = 15
  - LOI / FEGT = 5
  - Burner Profiler = 25
- **Planned Upgrade**
  - CO / O_2 Sensors
  - Optimization Software

Single Sensor Monitors CO and O_2

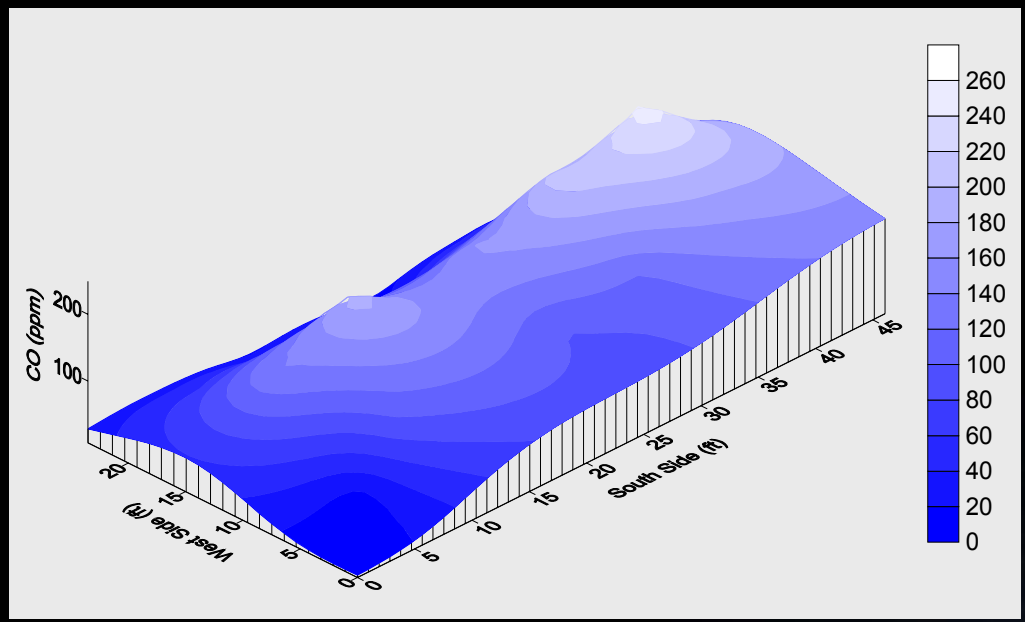
Combustion Optimization

Sensor Results (Before Optimization)

Combustion Sensors



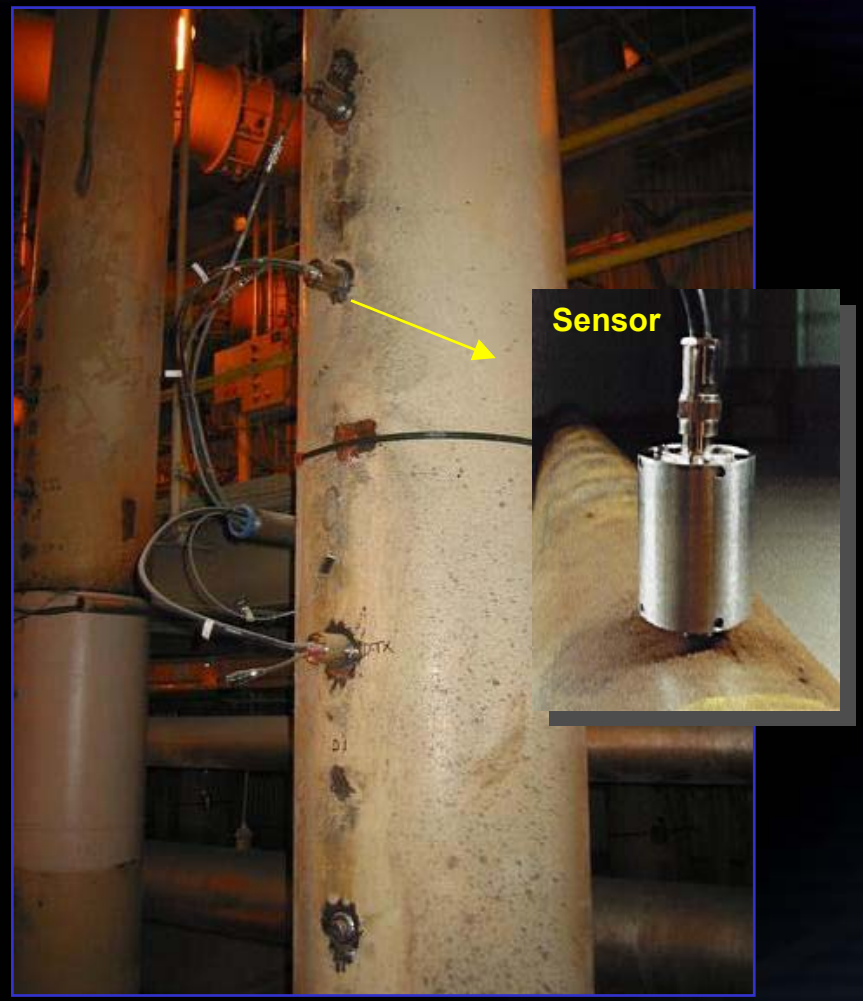
CO Sensor Data



Combustion Optimization

Coal Flow Monitoring & Coal Flow Control

Automated Coal Flow Dampers

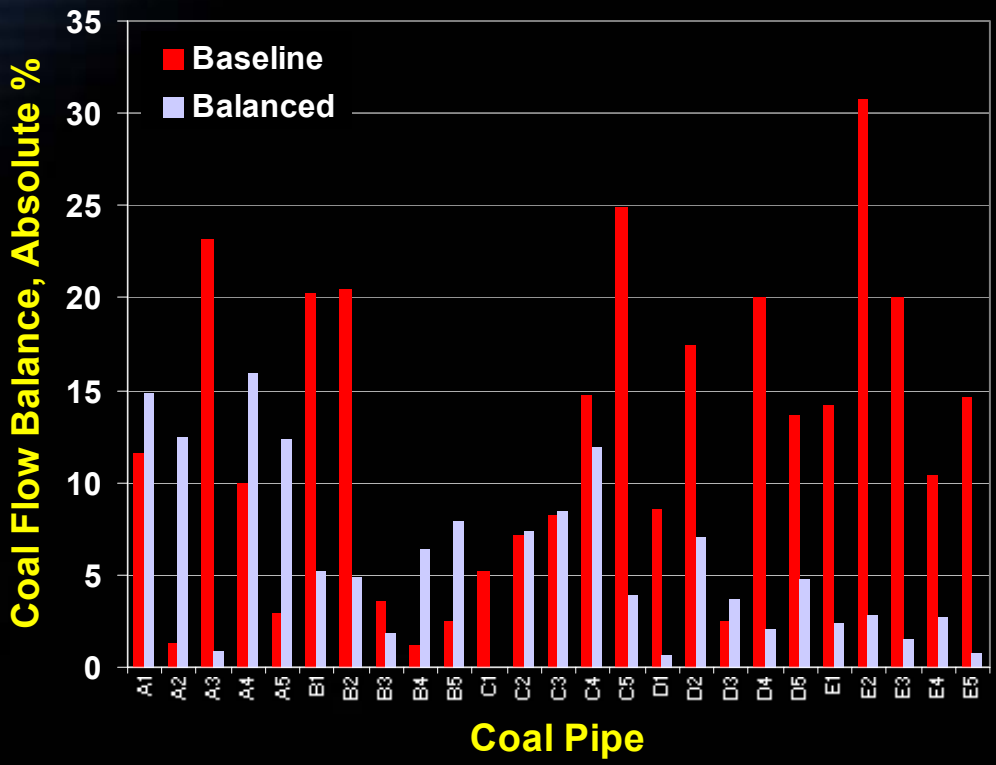


Coal Flow Sensors

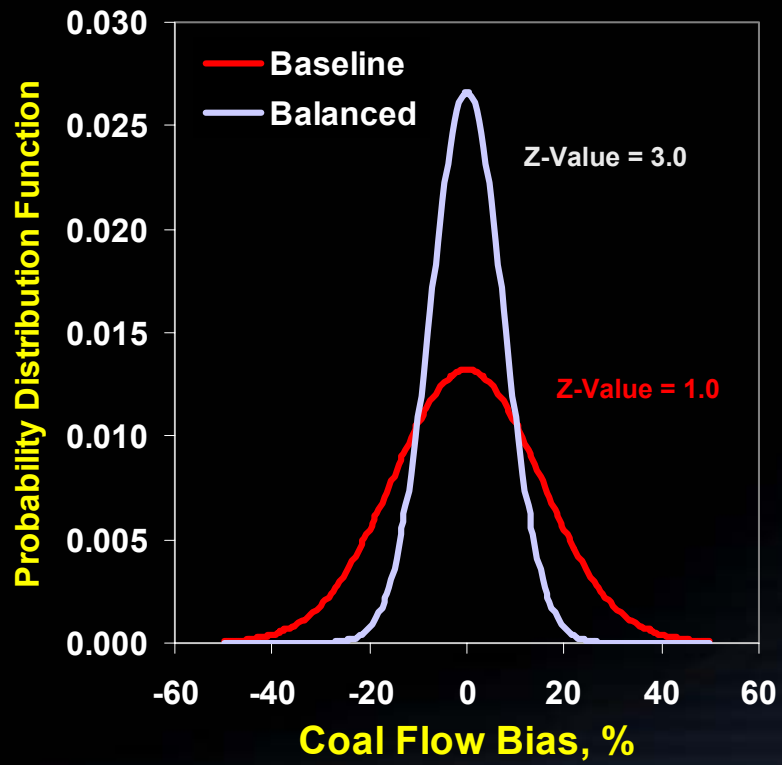
Combustion Optimization

Coal Flow Monitoring & Control

Mill Coal Flow Balance



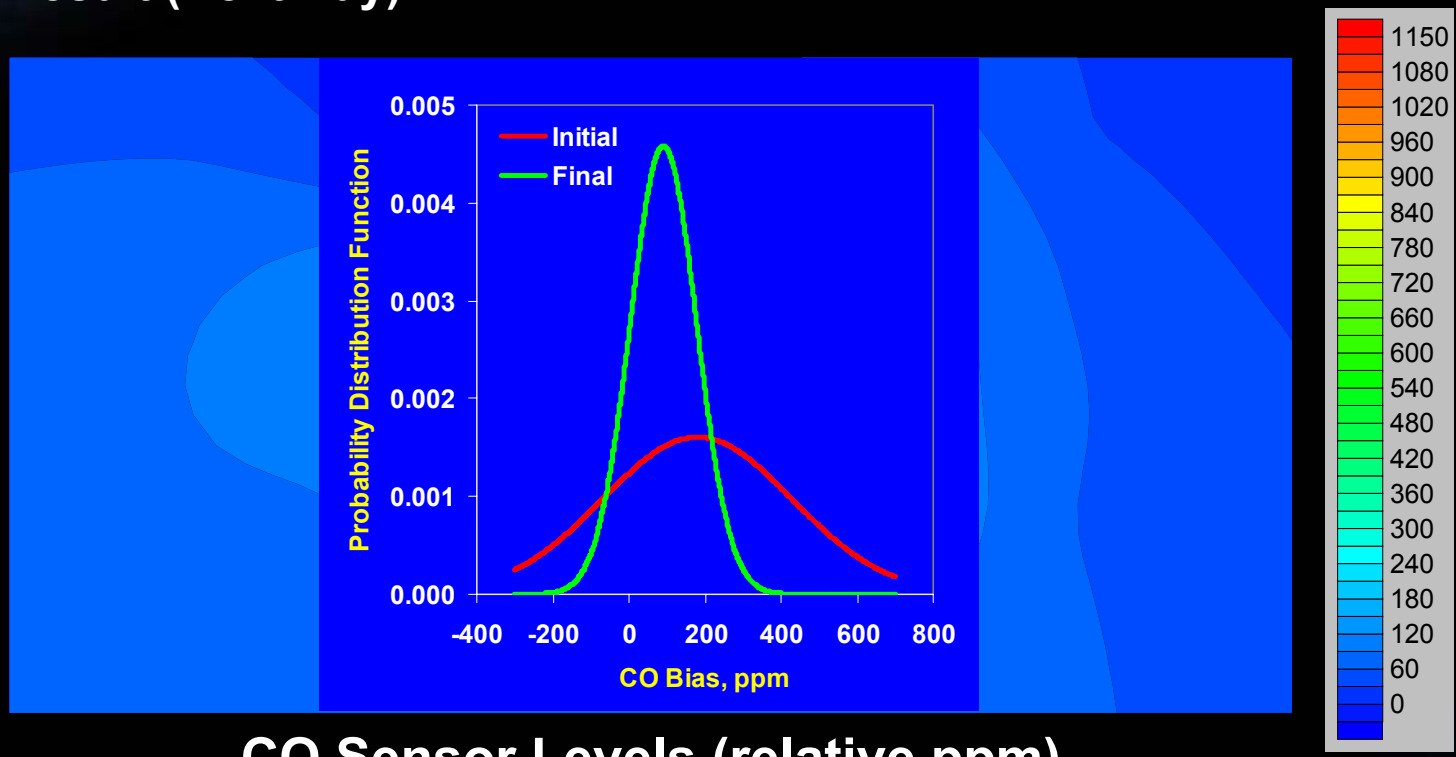
PDF
(Probability Distribution Function)



Combustion Optimization

CO Tuning Process – Sensor Data

Final Result (Next Day)



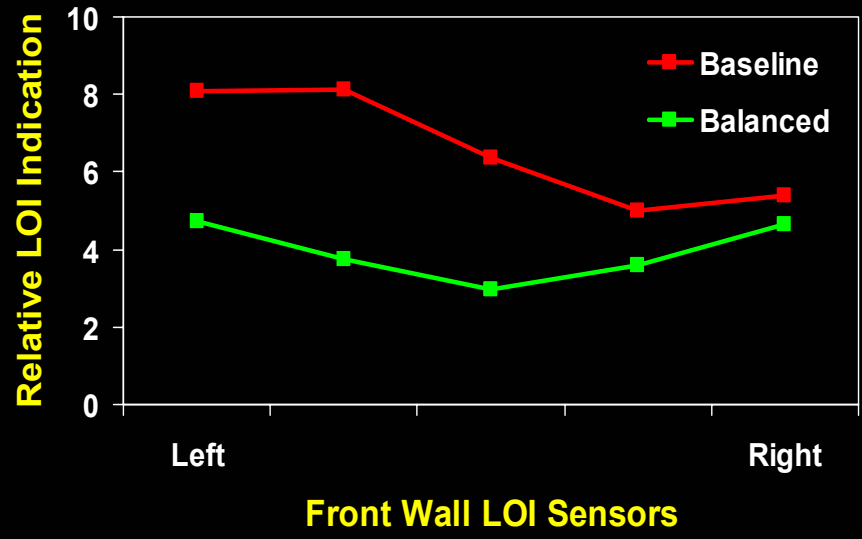
CO Sensor Levels (relative ppm)

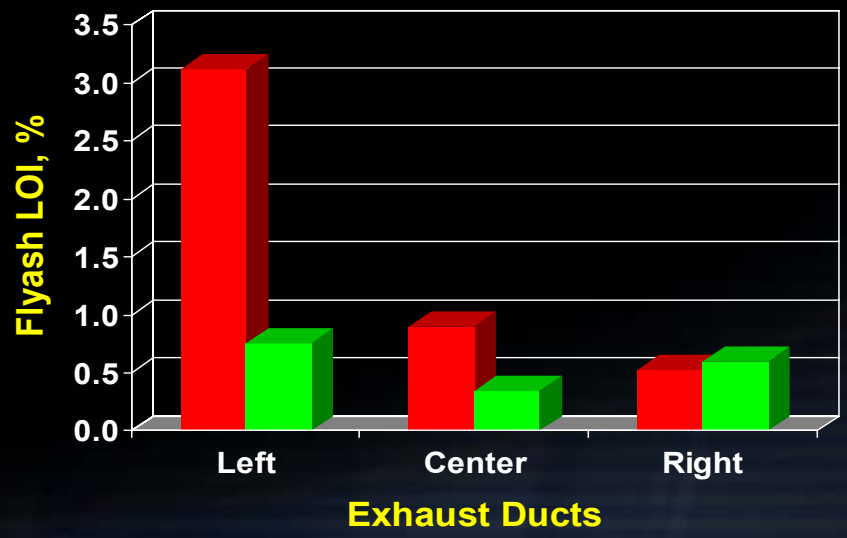
CO Imbalance Has Been Corrected

Combustion Optimization

Furnace Sensors

- LOI / FEGT sensors indicate combustion “quality”
- Provide side-to-side profile that can track furnace carbon burnout
- Allows for continuous response to changing combustion conditions





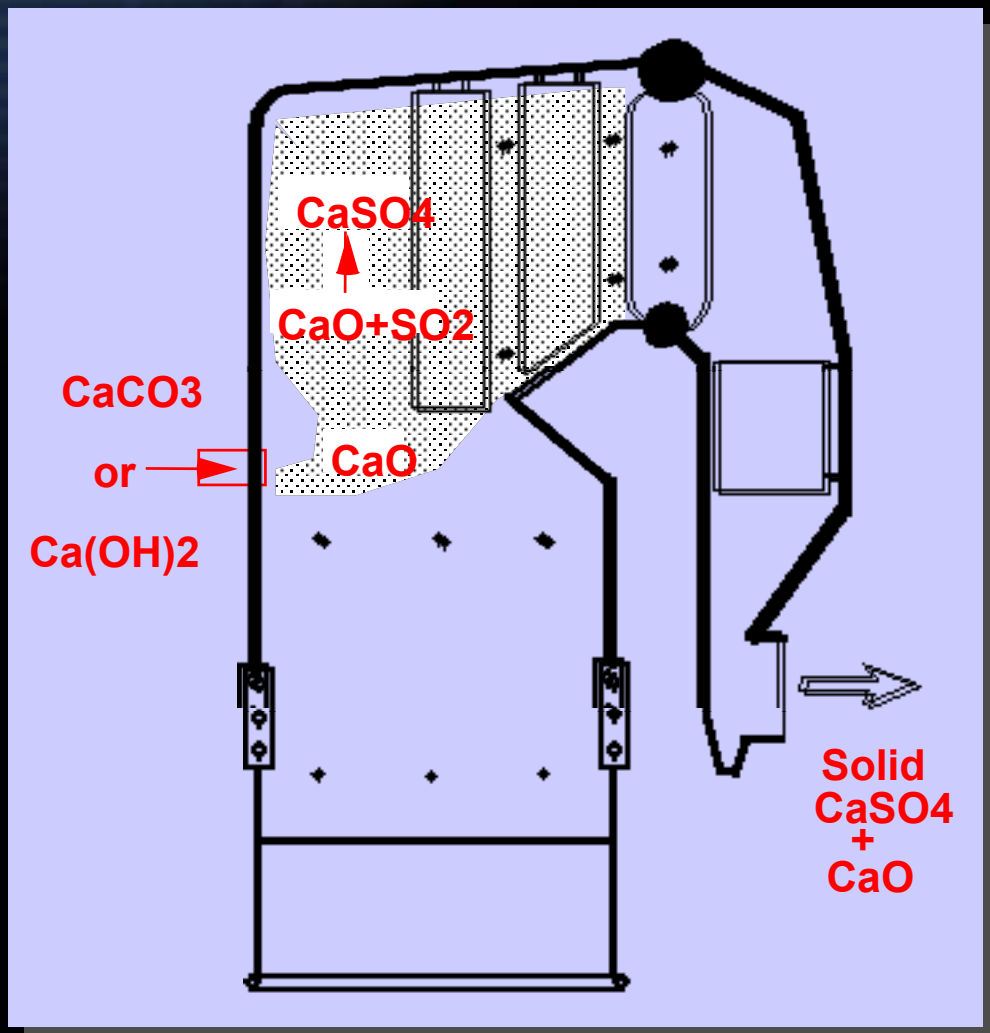
GE Integrated SO_2 Control Technologies

Sorbent Injection Schemes

- Lime and Limestone Injection
  - Integrated with Reburn and Low NOx Burners
  - Clean Coal Demonstration Projects
- Promisorb™
  - High reactivity hydrated lime sorbent for SO_2

Furnace Sorbent Injection

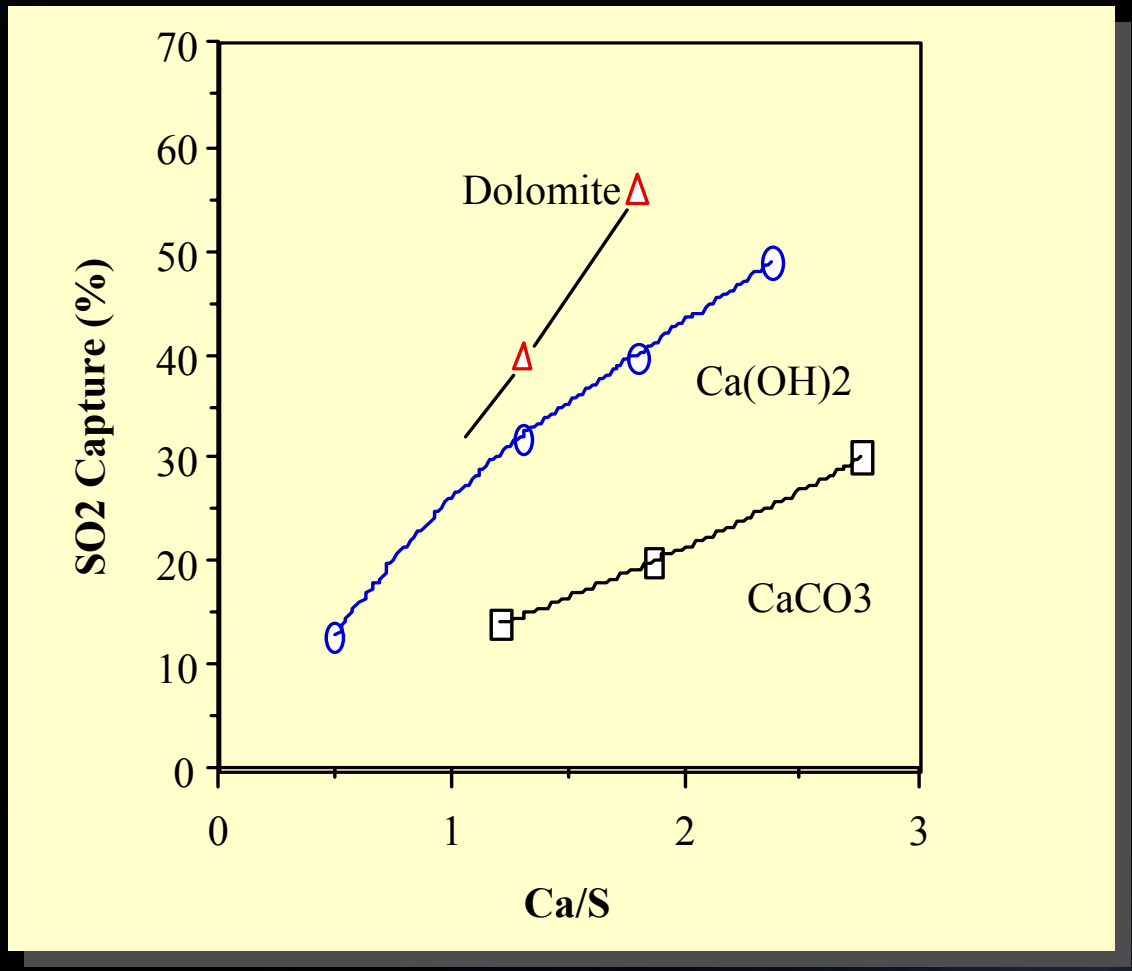
Sorbent Injection Process



- FSI process is well known and has been extensively demonstrated
- Economics and process impacts well developed
- Low capital costs, Simple to operate, Uses inexpensive readily available sorbents
- Sorbent utilization up to 25 - 30%
- Provides moderate levels of SO2 control up to 55~60%
- A highly cost effective SOx removal process for use as as stand alone or combined unit/plant solution

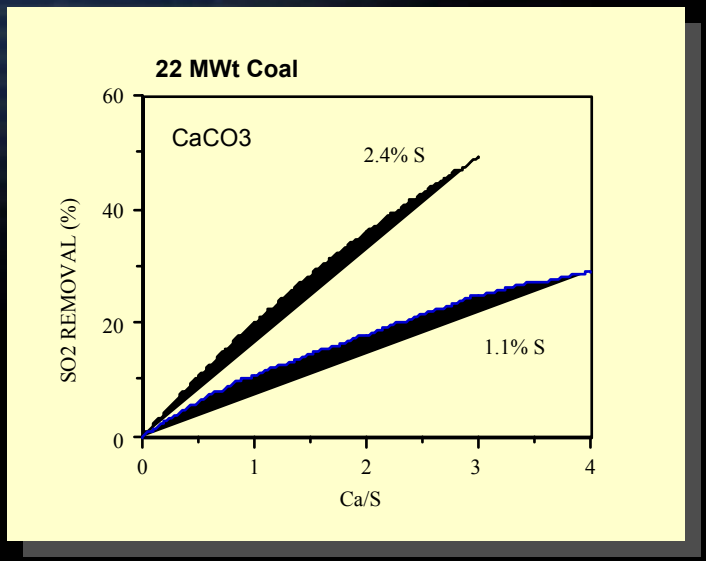
Furnace Sorbent Injection

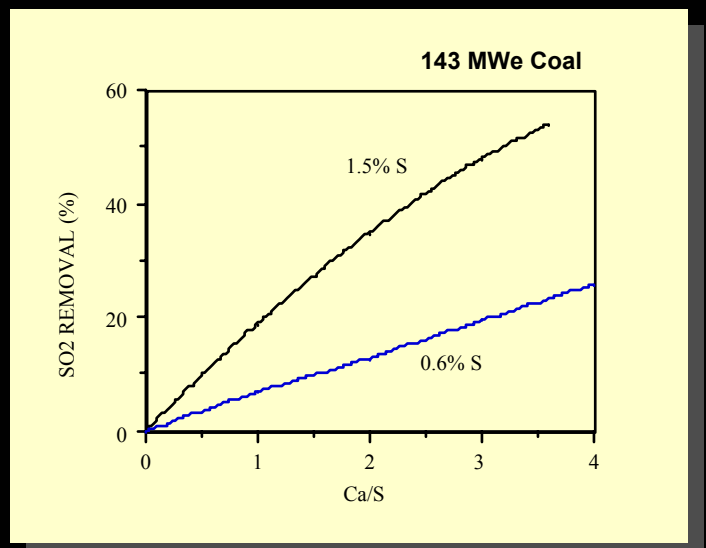
Typical Performance - Various Sorbent Types

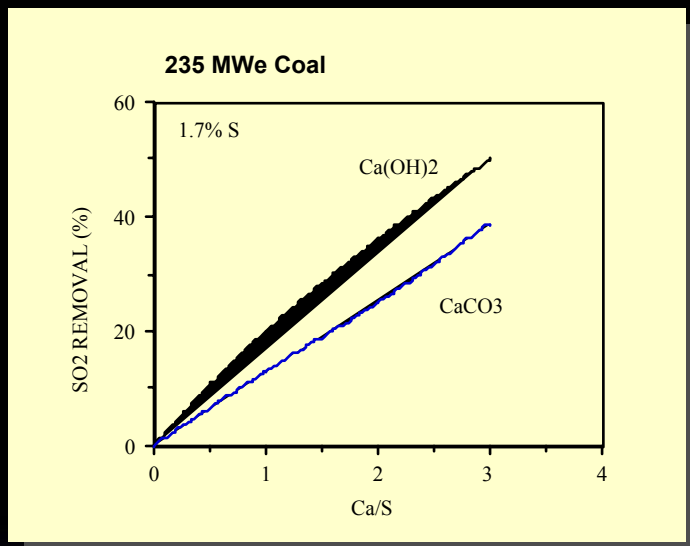


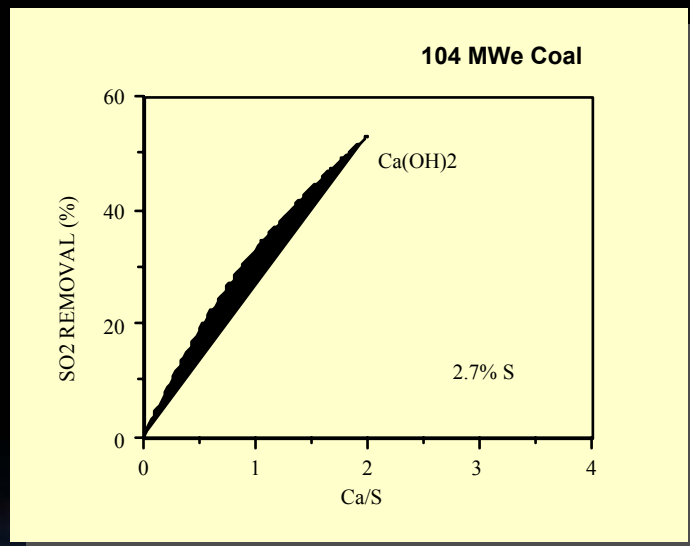
Furnace Sorbent Injection

Typical Boiler Sox Removal Performance Data



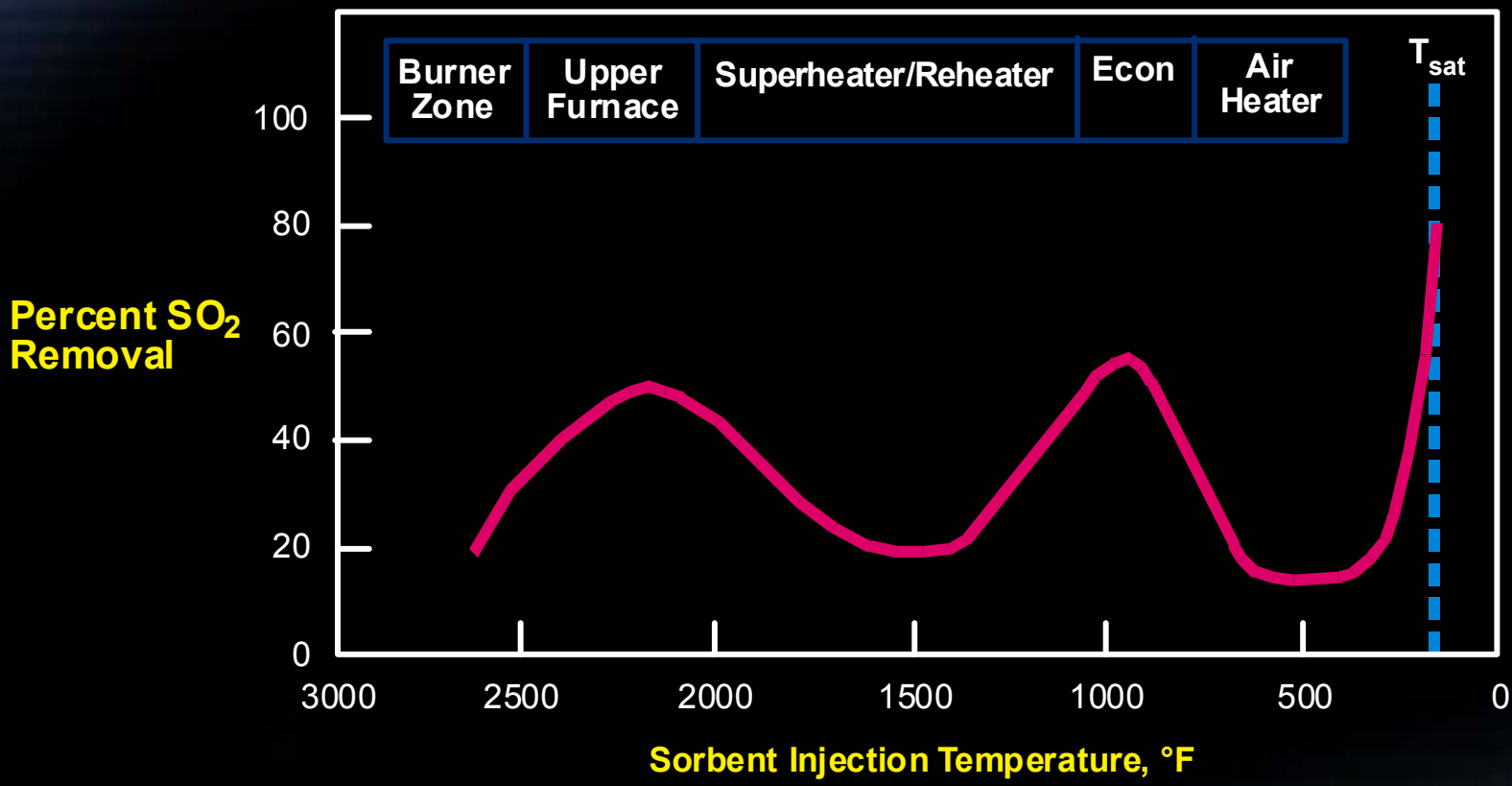






SO_2 Control

Capture by Hydrated Lime



(Rhudy, et al., November 1986)

SO_2 Control

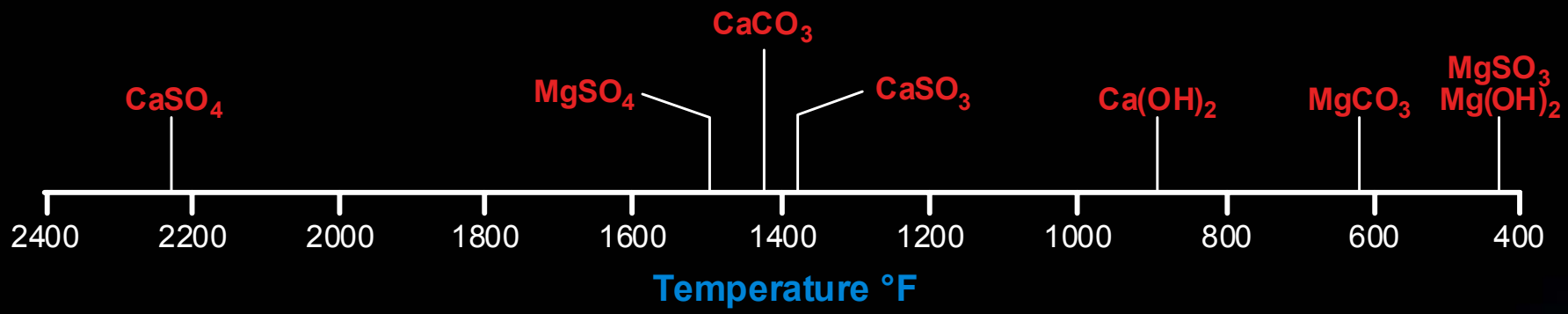
Capture by Hydrated Lime

$CaO = SO_2 + 1/2\ O_2 \rightarrow CaSO_4$

$CaSO_4$ Window

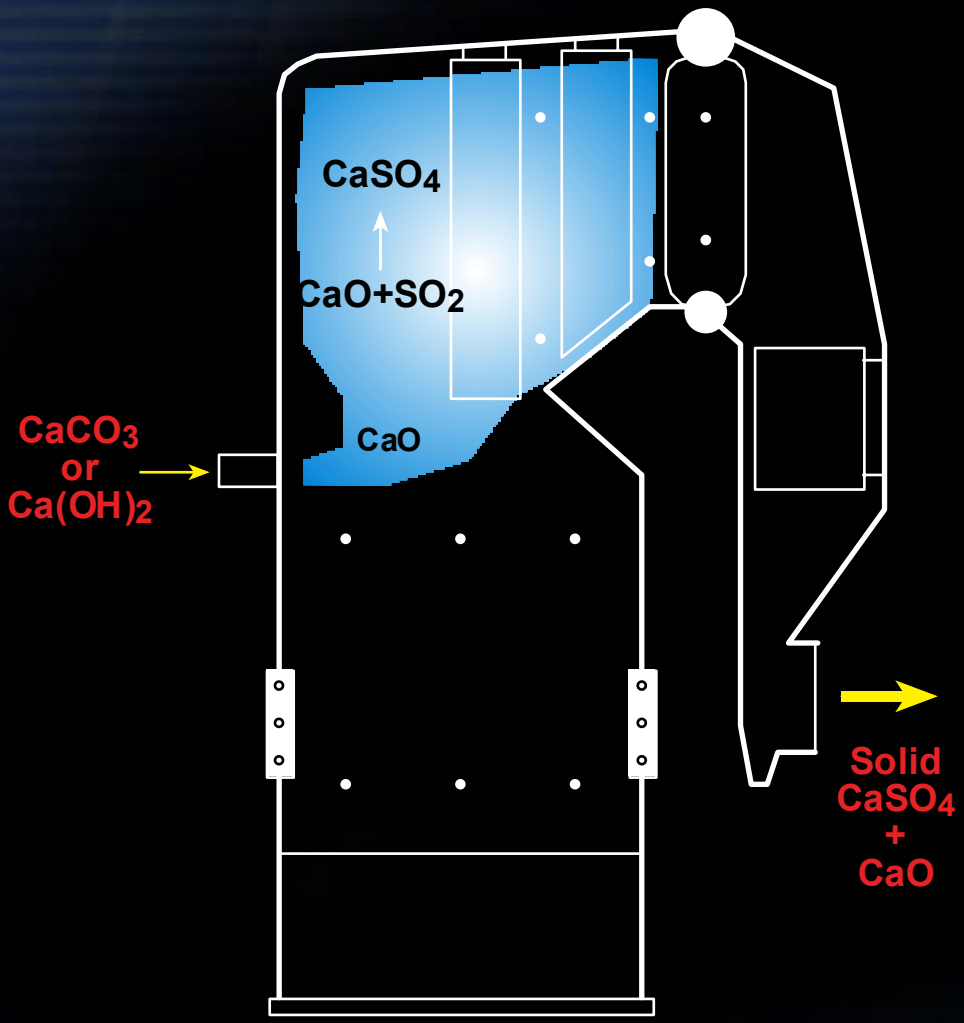
$Ca(OH)_2 + SO_2 \rightarrow CaSO_3 + H_2O$

$CaSO_3$ Window

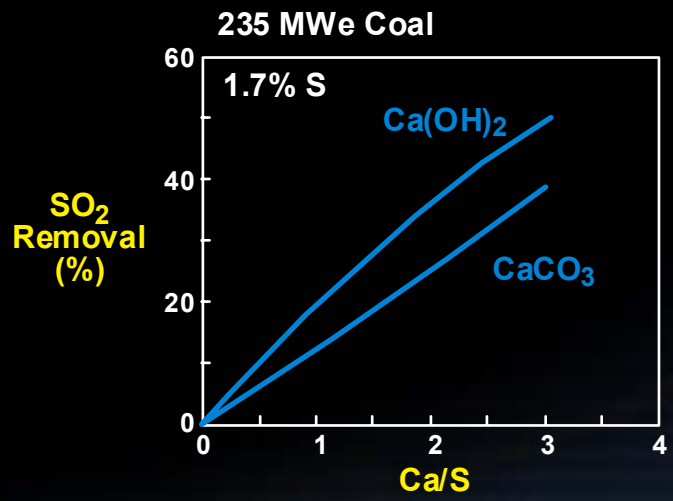


SO_2 Control

Furnace Sorbent Injection



- Very low capital costs relative to SCR
- Uses inexpensive sorbent operating materials



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Coalogic

. . . Gets the right coal to the burners at the right time

GE Optimization Services

Overview

A Coal Management Tool

- Gets the right coals to the boiler at the right time
- Tracks accurately all coals to the burners
- Recommends optimal coal loadings & blends based on emissions, heat rate & power demands
- Manages coal usage to maintain emissions
- Displays detailed data for all coals in the yard
- Calculates real-time fuel costs

Uses the Most Economic Coals at All Times

Proven Ability to Reduce Emissions

Successful Installations

- Blend high- and low-sulfur coals to maintain and not exceed SO2 and particulate dust limits
- Blend coals to avoid opacity and slagging derates using online data as feedback
- Potential to help with mercury and NOx emissions

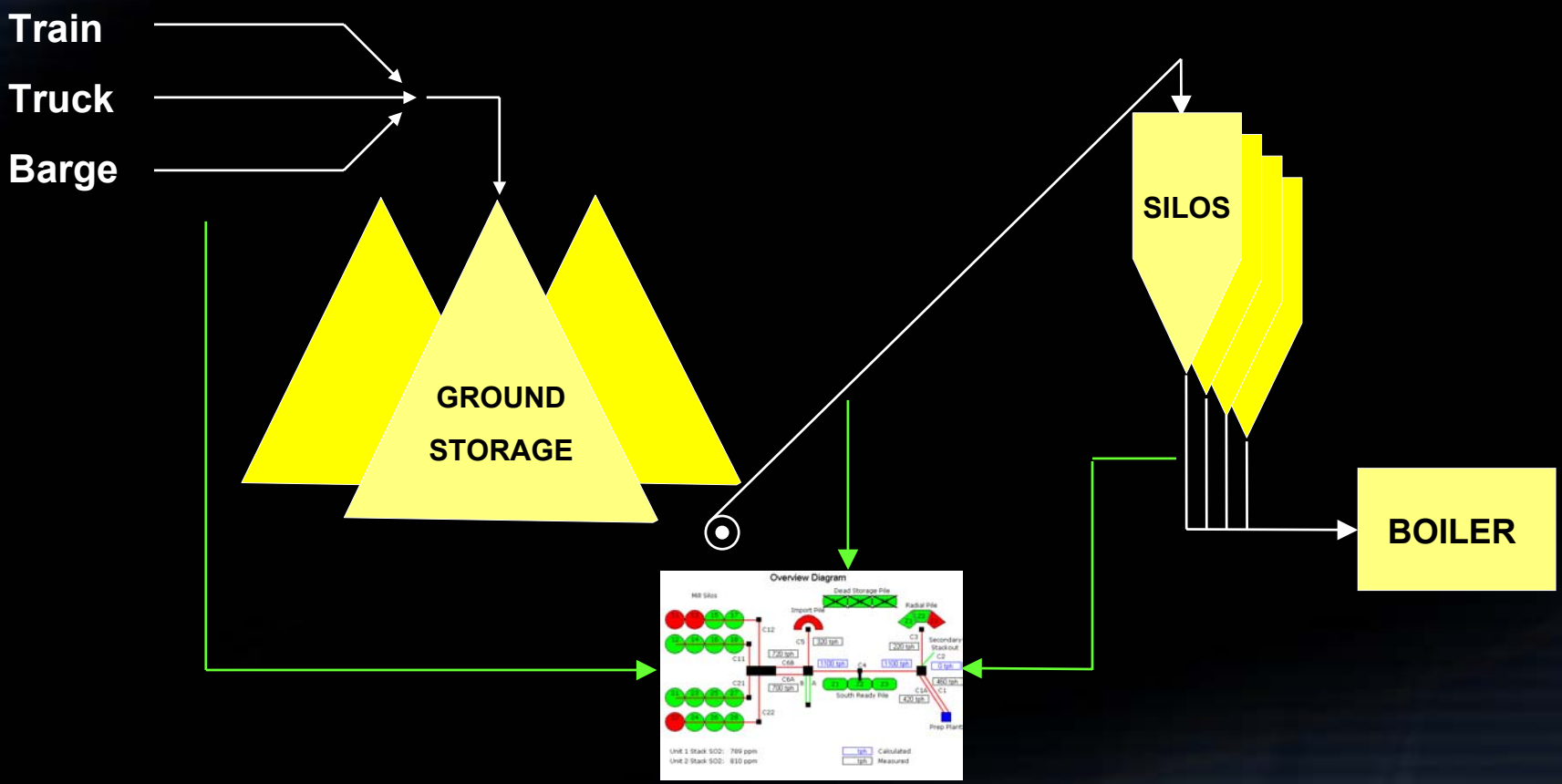
Annual Savings: $1 to $3 million per 1,000 MW

Over 30 Installations in North America

Coal Tracking Technology

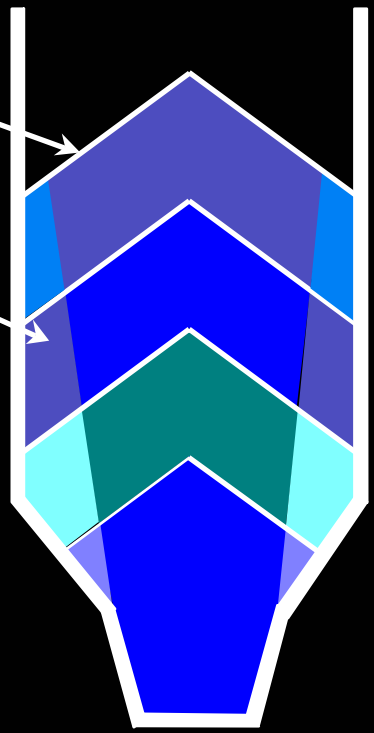
Accurate, Real-time Tracking from Receipt to the Boiler

- Uses detailed models for both yard equipment (conveyers, feeders, etc.) and coal storage devices (piles and silos), customized for each yard
- Uses online data from typical yard sensors as inputs



Silo Model

Three-Dimensional Model Calibrated for Silos



Most silos exhibit "funnel flow," not First In, First Out

Coal flow is very fast in center, slower towards sides

Dead zone moves only after center level drops

Works for various silo and pile geometries

Tracks Coal Through Silos, Bunkers, and Piles

Case Study: Centralia

Plant

- Centralia plant located in Washington State, US is a 2 unit, 800-MW total plant fed by local coal from a captive mine

Problem

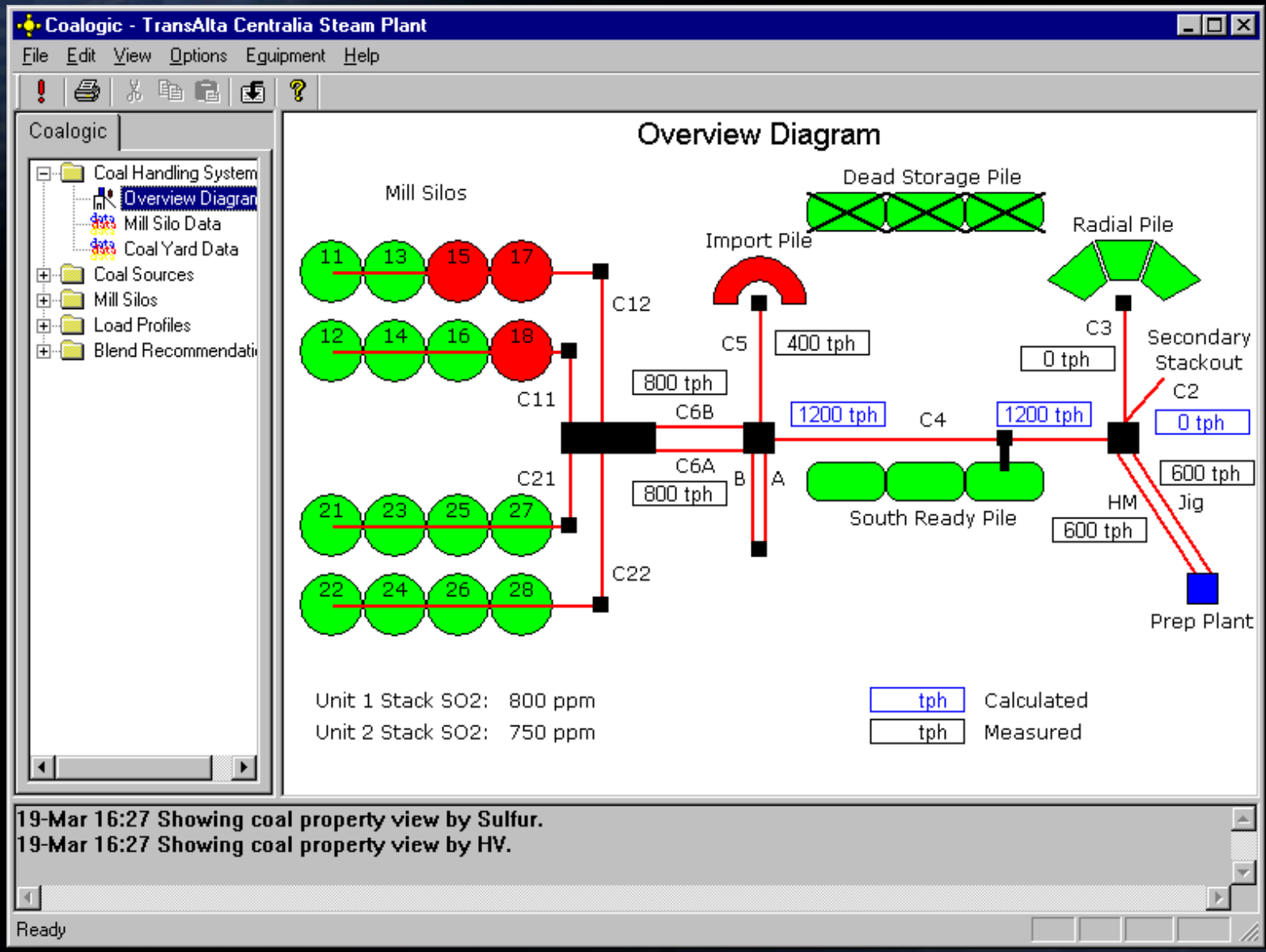
- Plant suffers from SO2-related derates and high mining costs
- Purchased low sulfur coal to help minimize SO2 problems but this is expensive…..how to manage optimal operation?

Solution

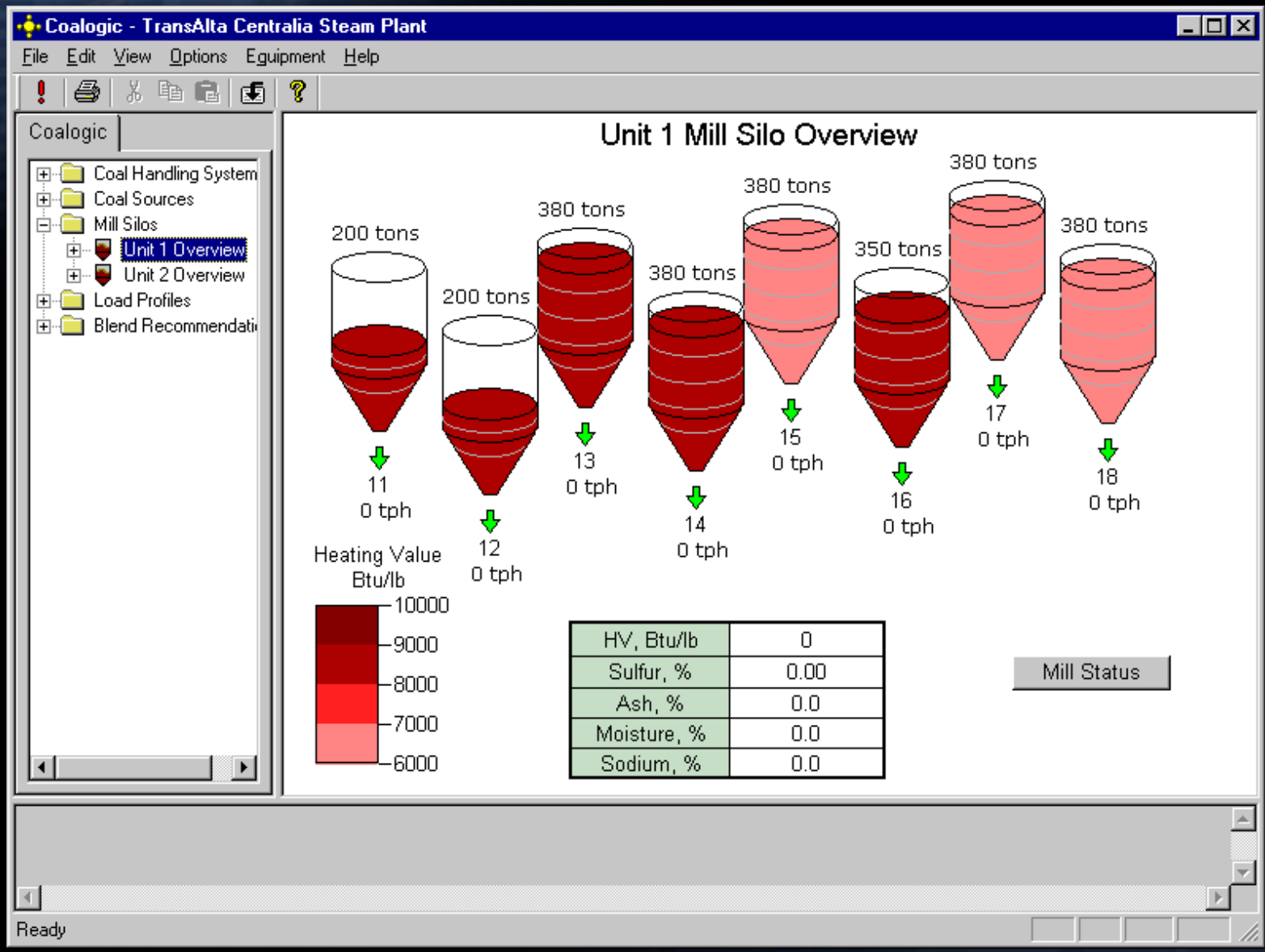
- Dynamically blend coals to maximize scrubber capacity at all times while meeting emission and Heating Value requirements
- Use higher sulfur but cheaper local coal and minimize the use of higher priced low sulfur coal (optimize the coal mix)
- Actual cost savings of $2 million annually in reduced fuel costs and improved derate performance, while meeting SOx emissions

Blending Sulfur the Hard Way at Centralia

Centralia Coal Yard Overview



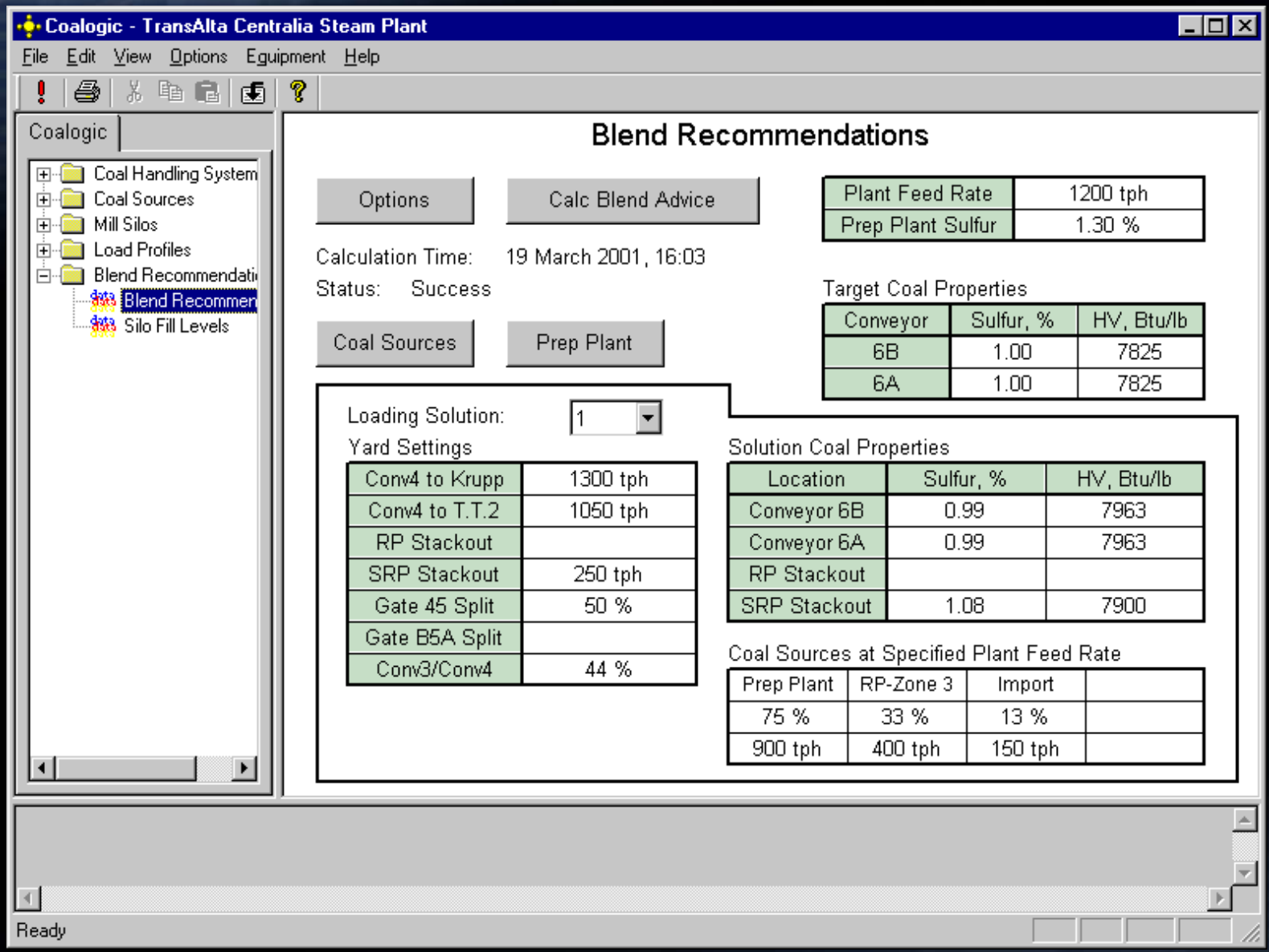
Centralia Bunker Overview



Centralia Blending Logic

- Determine target coal quality based on:
  - Desired stack gas SO2 ppm
  - Heating Value vs. MW load
  - Silo coal inventory
  - Recent stack gas SO2 trend
- Use coal tracking and blend search algorithm to find coal source combinations which will produce the target output coal quality (given the source coal quality, availability & yard constraints)
- Use measured stack SO2 as feedback to adjust coal blending to ensure operating constraints are met

Centralia Blend Recommendations



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GenGauge™

Real-Time Generation Costs for Economic Dispatch

GE Optimization Services

Overview

Portfolio Software Tool

- Calculates accurate real-time cost curves for fossil-fired units—automatically sent to the current dispatch control software for optimal dispatch decisions
- Works for both ultra short-term (AGC), short-term (dispatch), and long-term (unit commitment)
- Accounts for real-time variations in emissions costs – both SOx and NOx, which can have a major impact on dispatch, and allows extended operation of units & plants producing lower emissions

Accurate, Real-Time Cost Data for Optimal Dispatch

Current Dispatch Technology

Manual Process Using Static Data

- Fuel and emission costs and heat rates at different units are not known in real time
- Dispatch is based on long-term averaged cost data which are inherently inaccurate
- Incorrect cost basis for dispatch leads to significant reduction in profits

Inaccurate Data Leads to Non-Optimal Decisions

Dispatch Based on GenGauge

Automated Process Using Dynamic Data

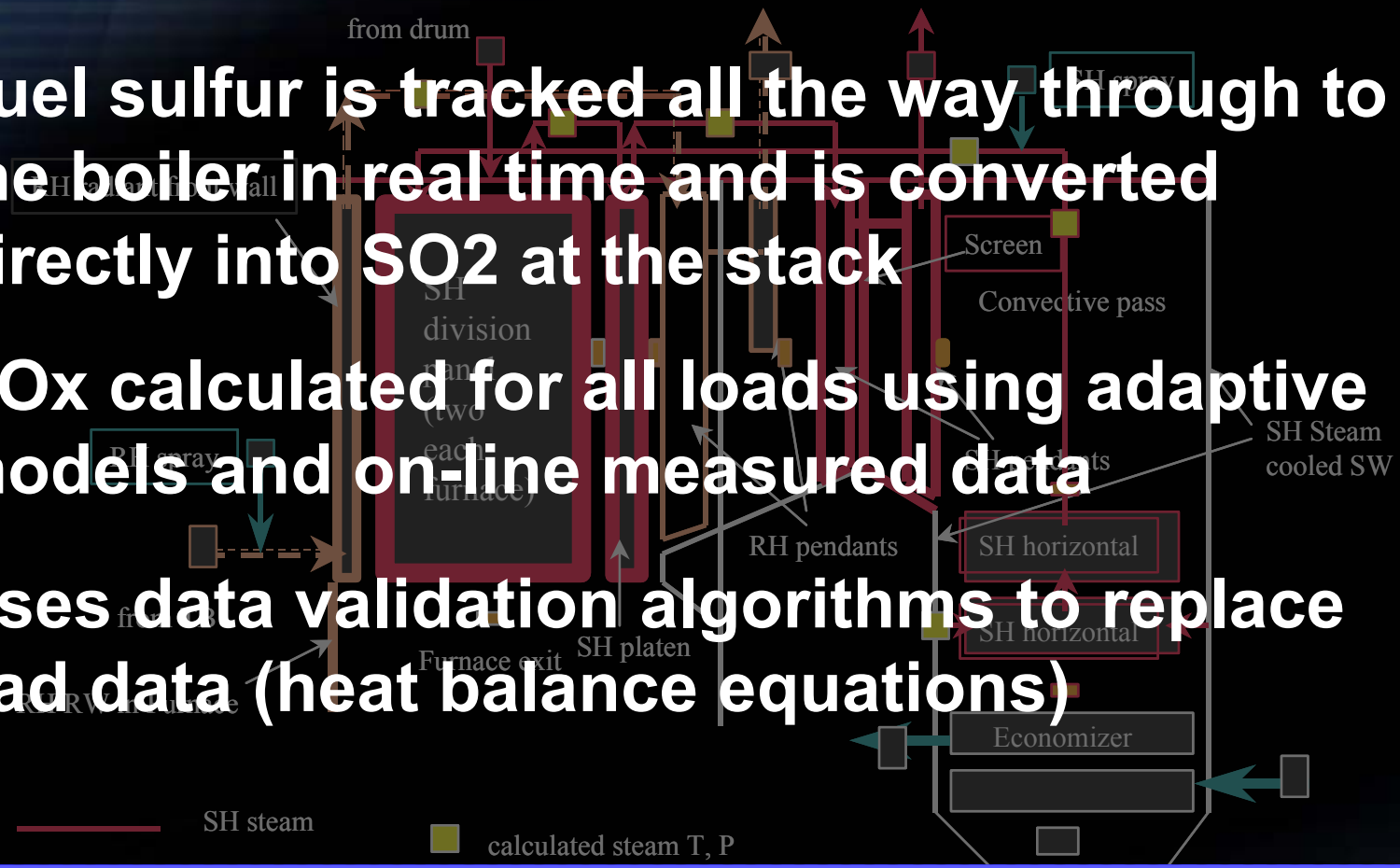
- All fuels are tracked in real time
  - Oil and gas prices are kept up-to-date for each unit
  - Coal quality and cost are tracked from stockpiles, through bunkers, all the way to the burners
- Heat rates for each unit—at any load—are accurately calculated in real time
- Emission costs (SOx and NOx) are calculated in real time based on fuel quality and performance modeling
- Using fuel costs, heat rate, and emission costs, cost curves for each unit are automatically updated
- Dispatch decisions based on real data improve profits

Accurate Data Leads to Optimal Decisions

SOx and NOx Tracking Technology

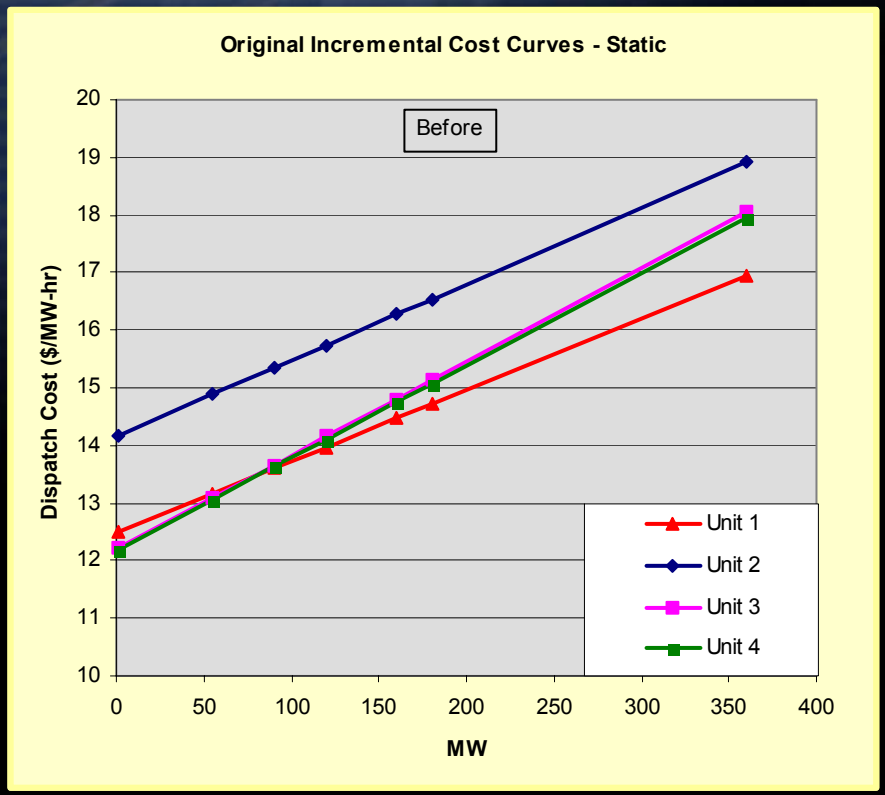
Accurate, Real-Time Emissions at Any Load

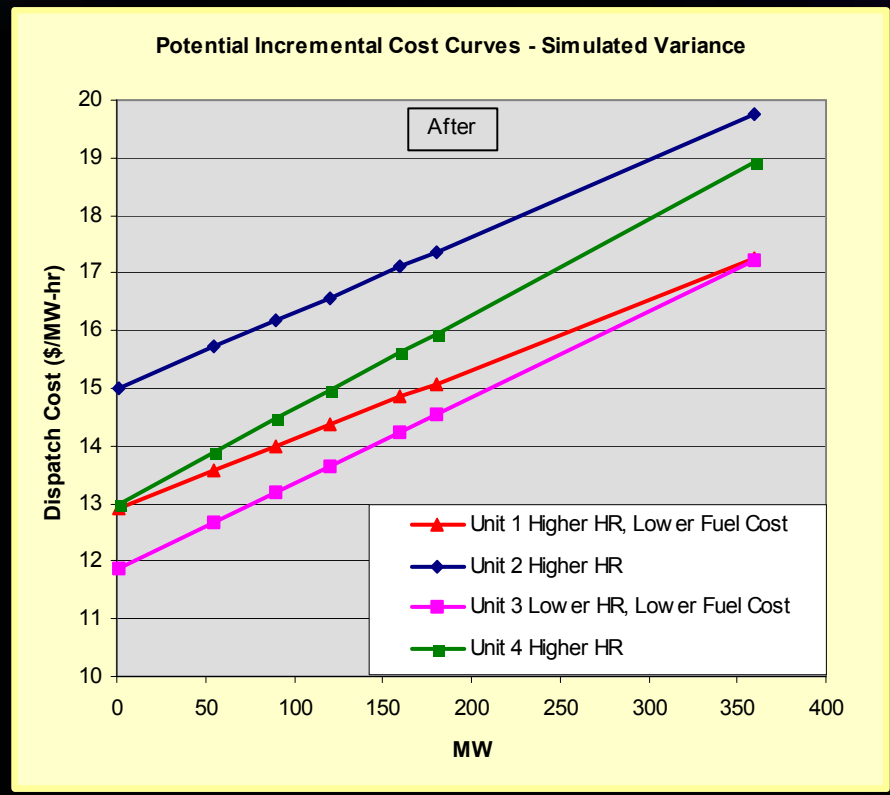
- Fuel sulfur is tracked all the way through to the boiler in real time and is converted directly into SO2 at the stack
- NOx calculated for all loads using adaptive models and on-line measured data
- Uses data validation algorithms to replace bad data (heat balance equations)



Real-Time Emissions Curve ➡ Real-Time Emissions Cost

Incremental Cost Curve Impacts





Current Static Curves Used For Dispatch

Real-time Curves Very Different Scenario

Unit 1 and Unit 4 would have been incorrectly dispatched at a higher rate due to inaccurate aggregate information

GenGauge Case Study

Installation at a US Utility

- Customer competitive Non-Disclosure Agreement in place
- GenGauge currently installed on 5,000 MW consisting of 3 plants and 12 units
- Total installation from start to finish took 9 months
- SOx and NOx related costs are 25% of the total cost and are updated in real time
- Product has been accepted and is being used daily
- Based on data from operation, savings are estimated at $2,000/hr for each hour the system is dispatched
- Payback: ~ 12 months (depends on customer conditions)
- Takeaway: Huge potential for all generators to save costs

Customer Installing at 2 Additional Plants Based on Results

GE Integrated Solutions Approach

Phase 1
Plant Performance Evaluation

Plant Performance Evaluation Service

- Independent Failure Mode Analysis
- 1 - 2 Day Onsite Service with Exit Interview
- Plant and Data Analysis and Observations; Operator Discussions; Mass & Energy Balance; Efficiency Calculation
- Recommendations

Phase 2
Boiler and Turbine Engineering Analysis

Engineering Solution Analysis Service

- Detailed Root Cause Analysis
- Boiler and Turbine Modifications Performance and Economic Assessments
- Solution Recommendations
- 8-12 Weeks Engineering / Progress Meetings
- Thermal, Fluid-Dynamic, Combustion Models; Emissions Correlations; System Engineering
- Technology Trials / Demonstrations (Additives/Sensors)

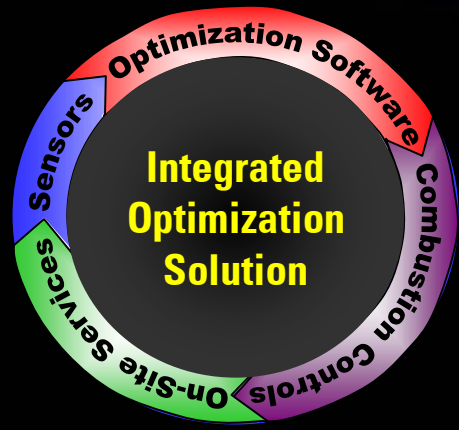
Phase 3
Design Engineering, Installation and Optimization

Plant Improvement Projects

- Turn-Key Project Management
- Boiler Systems Engineering Design
- Construction and Installation
- Commissioning, Optimization and Controls System Integration

Conclusions

- GE's Integrated Solution Improves:
  - Performance
  - Operator Productivity
  - Cost Savings
  - Overall Plant Profitability



- Cost-Effectively Reduces Emissions (NOx, SOx, CO, Hg)
- Features Commercially-Available, Proven Products
- Can Enhance Operations and Decision Making
- GE develops Project from Concept to Site-Specific Evaluation to Full Commissioning

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